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Acronyms and Abbreviations

ESA	European Space Agency
JSC	Johnson Space Center
mm	millimeter
MSIS	Man-Systems Integration Standards
NBP	neutral body posture
STS	Space Transportation System

Introduction

Past research from the Mercury, Gemini, Apollo, and Skylab Programs (and, more recently, from the Shuttle missions) has shown that the space environment induces physiological changes in the human body. Among these changes are fluid shifts in the upper body and chest cavity, spinal lengthening, and muscular atrophy. Additional changes include space motion sickness, cardiopulmonary deconditioning, and bone mass loss, as well as some changes in visual perception. These require a period of adaptation and can substantially affect both crew member performance and posture throughout a mission. These physiological effects have been of particular interest for posture studies and, when work activities are conducted, have been known to impact the body's center of gravity, reach, flexibility, and dexterity. Additional posture considerations include attention to the range of crew member body size and the possibility that a crew member's posture may change over mission duration. All these aspects of posture must be considered to safely and efficiently design space systems and hardware.

In an effort to develop an overall posture on the subject of space-induced physiological changes in the human body, NASA has documented its microgravity body posture in the Man-Systems Integration Standards (MSIS) (Fig. 1). The MSIS posture is generally used by the space community in the design of workstations and tools for space application.

Please refer to hard copy of document for figure.

Figure 1. MSIS neutral body posture (NBP)

However, the European Space Agency (ESA) has suggested that NASA's microgravity body posture be further investigated for a number of reasons. These are:

- Small sample size: NASA's original determination was based on a small sample of Skylab crew members and in-flight photographs.
- Possible imprecision: The reference points used to measure the joint angles were not very precise because they were obscured by clothing.
- Lack of detail: Limited literature from the Skylab missions only superficially described experiments conducted on Skylab.

After investigating photographs and video taken during the Skylab mission, ESA reported that only 36% of the data reviewed matched the NASA microgravity body posture that is graphically portrayed in the MSIS. Because of the questions ESA raised, further investigation was deemed necessary.

This study was undertaken by the Human Factors and Ergonomics Laboratory at the Johnson Space Center (JSC) to investigate human body posture exhibited under microgravity conditions. STS-57 crew members were instructed to assume a relaxed posture that was not oriented to any work area or task. Crew members also were asked to don shorts and tank tops and to be blindfolded while data were recorded. This was done to facilitate the acquisition of non-orientation posture as well as to ease the visibility of body segments and limb angles. This effort from the STS-57 (SPACEHAB-1) mission was a means of acquiring video data with minimal hardware requirements and as nonintrusively as possible. Due to mission constraints, video data were only acquired once during the mission from each of the six crew members. This study was a first attempt at gathering specifically selected video data and working out methods and procedures for acquiring more quantitative data from future missions.

For the STS-57 mission, several crew familiarization briefings, as well as training sessions in the full fuselage trainer, were conducted at JSC. Data were acquired from several crew mission debriefings. A detailed discussion of these data and findings are reported below.

Method

Video and still photography were the primary means of acquiring data on microgravity posture for this mission. This option was chosen to expedite data acquisition and to accommodate stowage, weight, and time limitations on the STS-57 mission. Past data acquisition had focused on video as a means of assessing posture. To provide additional relational data with which to develop a posture database, video was also selected for this study. Camera placement location was carefully chosen within the constraints of the middeck volume. The camera locations approximated 90• placement as closely as possible. Only 30• placement was possible because of the middeck’s rectangular shape and narrowness (Fig. 2). The two video cameras and the one still camera for this study were oriented in the same focal plane to provide similar perspectives from the two data types.

Previous video data from Skylab were taken from a handheld still camera and were analyzed by hand. In the current study, we sought to investigate the use of a more automated and objective method. Thus, special software developed by NASA was used to select individual video frames that coincided with the still shots. This software was used to define an individual’s posture from the limb and joint angles identified from the data.

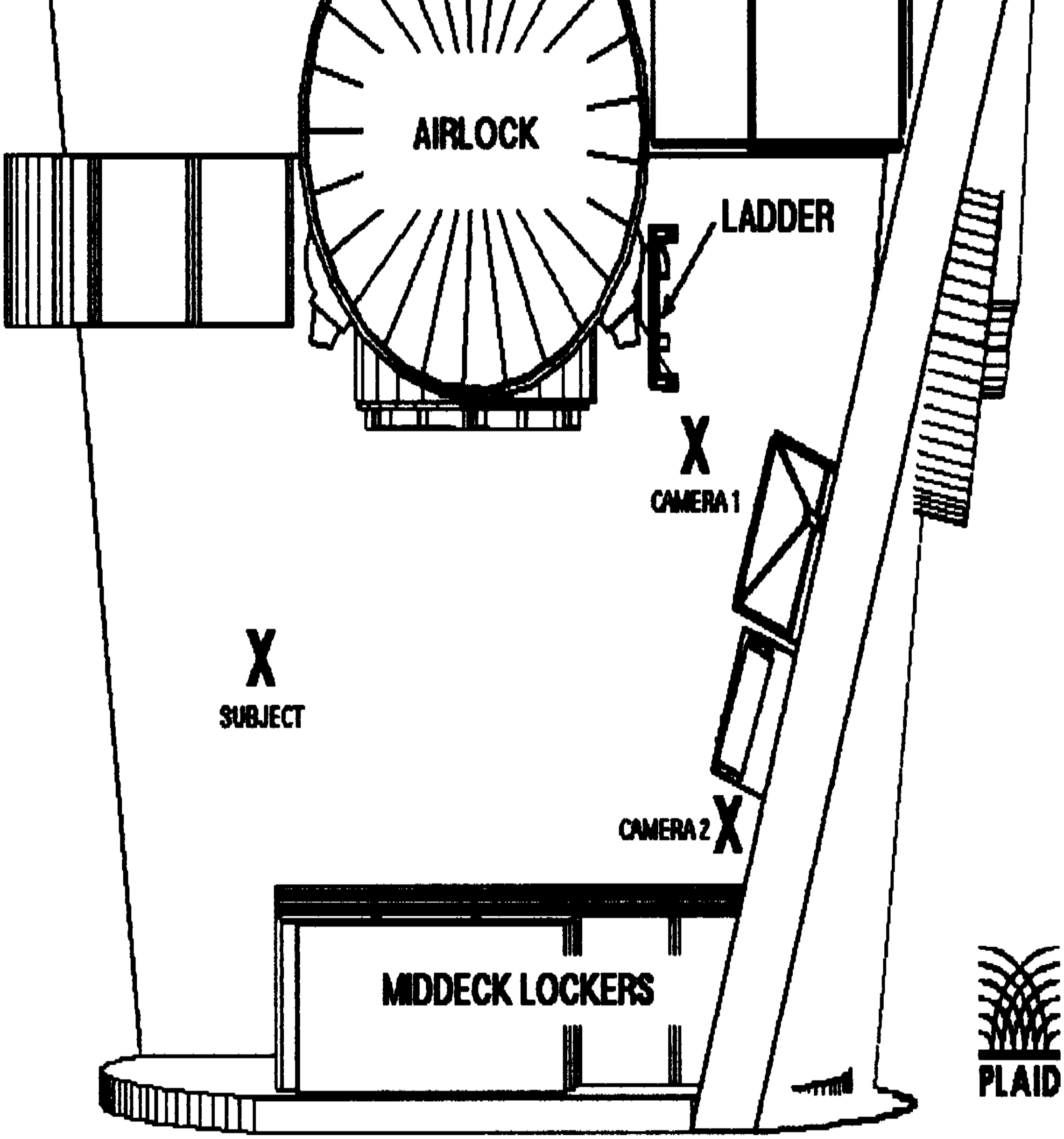

Figure 2. Experiment set up at the middeck showing approximate location of the two video cameras

Subjects

General anthropometric body measurements were taken of all six STS-57 crew members prior to flight. In all, 26 different anthropometric measurements were taken in the Anthropometric and Biomechanics Laboratory at JSC. Representative measurements included weight, stature, arm reach, thumb tip reach, shoulder height, and knee height (Appendix 1). The crew represented 5th to 90th percentile in anthropometric stature. There was one female at the 5th and one female at the 75th percentiles; one male at the 50th and one male at the 90th percentiles; and two males at the 75th percentile. All six crew members participated in on-orbit testing. The diverse range of anthropometric body types on the STS-57 mission provided an extraordinary opportunity for gathering the data necessary to begin assessing posture and for defining the effects of microgravity on posture.

Apparatus and Materials

Two Canon Mark II video cameras were used to record the video data. These video cameras used wide-angle lenses (0.7) to accommodate the small space of the middeck. Available middeck lighting was used. A Nikon F4 with a wide-angle lens (0.7) and a flash was used to take still shots. The Canon and Nikon cameras were mounted to their positions using standard Shuttle bogan mounts with clamps. The film used in the Nikon was CNEG ASA 100, 12 exposure rolls. The cameras, camera-mounting equipment, flash, lenses, video tape, sleep masks, shorts, and film were all Government furnished equipment that required no additional flight certification or review. The tank tops used by the crew were specially furnished and approved for flight.

Experiment Data

NBP video data were provided to the experimenter on two separate 8 mm tapes; one from each video camera used in the study. These data were also provided to JSC where they were archived with the other mission video and downlink. Video data from the two NBP tapes were then synchronized and transferred onto one video tape in VHS format. One of the synchronized tapes allowed the researchers to view the various body angles together for easier and more consistent analysis. Specific portions of the video were selected based on consistency of body posture and position. These images were used to construct still video frames for further analyses. Body positions and joint angles were obtained using specialized anthropometric software and were compiled into data tables for each crew member. These data tables were directly employed in constructing wire-frame representations of the various crew postures for comparison with the MSIS NBP.

Procedure

The crew were positioned in Endeavour's middeck in front of the sleep stations (over the trash stowage compartment located on the floor of the middeck, towards the aft bulkhead). Two video cameras were located on the opposite (starboard bulkhead) wall. The still camera was mounted to the ML98D panel located on the starboard bulkhead of the middeck. This camera was purposely placed at the midpoint between the two video cameras and in the same focal plane to provide synonymous data. One video camera was mounted to the experiment handrail on middeck locker face MF14E; the other video camera was mounted to the middeck ladder that provided access to the aft flight deck. The video cameras were mounted to their respective locations using bogan arms and clamps. Video tape and 35 mm still shots (photographs) of the crew were taken once, late in the mission on flight day six. The video cameras were set up and the video tape was run continuously to acquire all six crew members' postures at relatively the same time. A flash was used with the 35 mm camera to synchronize video and still shots for easier data analysis. Video camera tapes were recorded in the Hi8 setting. Crew postures were recorded as crew members were rotated 360• in 45• increments. Crew members were dressed in tank tops and shorts to facilitate viewing the body joints and limb angles. A sleep mask was used by the subjects to encourage relaxation and non-orientation to any workstation or task area.

Still shots were taken of the video camera setup and position to record the exact location of the cameras during data acquisition. Crew members generally arrived in the middeck in shorts and T-shirts. They then donned the sleep mask and assumed a neutral posture. The attendant crew member rotated the crew participant to the appropriate orientation for the data to be taken. Crew participants were rotated 360• in 45• increments to provide video and still shots from as many angles as possible. At least two still shots of each position were obtained in each of the incremented positions. The flash from the still camera was used to synchronize the video. These were combined with still video shots to form 3-dimensional wire-frame views of the crew's NBP.

Results and Discussion

Data analyses were conducted using software specially developed by NASA to determine the joint angles and limb positions of each crew member. Video frames from camcorder data were specifically selected and matched with still photos to derive 3-dimensional wire-frame representations of crew postures. These postures were compared to the MSIS NBP posture to determine the apparent range of differences in posture, if any.

Analyses of mission data indicated that several different crew postures were exhibited during data acquisition on flight day six. Appendix 2 contains eight selected mission photographs that provide representative data on which analyses were conducted. Data acquisition on day six allowed the crew to become fully adapted to the microgravity environment and provided time to recover from any ill effects that space motion sickness may have induced. As shown in Figure 1, no single crew member exhibited the typical NBP called out in the MSIS. Figure 3 shows the posture of each crew member from front and side views, respectively.

Please refer to hard copy of document for figure.

Figure 3. NBP of the STS-57 crew members

Generally, the arm and shoulder positions exhibited by crew members were less bent and leg positions were straighter at the hip and knee than the MSIS neutral posture. Crew posture data also showed the arms closer to the torso sides and generally held lower toward the waist. The MSIS neutral posture figure indicated arm positions closer to the mid chest area with the elbows away from the body (Fig. 1).

Specifically, three male and two female crew members exhibited NBPs that were more elongated or less bent at the hips and knees than the MSIS NBP. The lower arm and hand positions showed a range from shoulder height to waist height. The separation between hands ranged from a shoulder width apart to nearly touching in front of the crew member.

Extreme aspects in posture were exhibited by three crew members; two females and one male (Fig. 3; crew 2, 5, and 6). The male showed a posture that was very different from that of the other five crew members (Fig. 3; crew 2). His posture showed a stance that was shifted forward with the knees pointed down and the legs at almost a 45• angle to the floor. His arms were also more elongated at the shoulder and elbow, in a forward position with the fingers curled at the knuckles. One female had deviations in her posture focusing on the leg and foot regions (Fig. 3; crew 5). Her posture data showed the legs very close together, nearly touching along the inner thigh, at the ankle, and at the inner foot arches. The second female's posture was almost erect, with only slight bending around the knees and at the neck (Fig. 3; crew 6). Her legs were closer to the MSIS neutral posture than were the other female's. However, her posture data showed that her arms were lower and closer to the body and waist than to her mid chest region, as compared to the MSIS neutral posture. Another area of variation was neck positions.

This variation was found with two crew members (Fig. 3; crew 4 and 5). These two crew members exhibited relatively straight necks in combination with the elongated posture discussed previously. The other four crew members exhibited bent necks similar to the MSIS neutral posture. One additional deviation was found with a male crew member who exhibited a forward pitch to his back in combination with the bend in the neck area (Fig. 3; crew 1).

Because of these deviations from the standard MSIS NBP as discussed here, one composite posture may not be adequate. These findings suggest that construction of several composite postures or a range of postures may be more constructive for design purposes. Table 1 shows the joint angles in degrees for individual crew members.

In general, three main postures were exhibited by the crew as a whole. These constituted (1) an almost standing posture (Fig. 3; crew 6), (2) a slightly pitched forward posture with an extreme bend at the knees (Fig. 3; crew 2), and (3) an elongated posture with a straight neck (Fig. 3; crew 4 and 5). Differences in posture exhibited in this study could be a result of the athletic bearing of the participants or the type of exercise, or both, and the amount of exercise regularly performed. Other differences may also stem from past physical injuries such as bone breaks and knee or shoulder injuries, and from gender differences such as center of gravity. ESA reported that discrepancies found in posture could be owing to cultural differences and physical injuries affecting joint rotation and flexibility. Another factor cited by ESA was the deviations brought about by the participants not being blindfolded, which oriented them to a work area and predisposed their posture orientation. Additional factors affecting posture may include physical typing based on skeletal build and the fat-to-muscle ratio of the participants. This would tend to be highly related to additional anthropometric considerations such as percentile characterizations for specific body segments and joint motion and flexibility differences which could also affect stance and posture.

Table 1. Crew NBP Measurements

Anthropometric Measurement Joint Angles	MSIS NBP Left-Right	Crew 1 Left-Right	Crew 2 Left-Right	Crew 3 Left-Right	Crew 4 Left-Right	Crew 5 Left-Right	Crew 6 Left-Right
Hip flexion	50	33	33 - 29	33	33	29	12
Hip abduction	18.5	6.5 - 5.5	20 - 16	13 - 17.5	15.5 - 16	3.5 - 4.5	4 - 9
Knee flexion	50	50	83 - 87	50	50	44	11 - 12
Ankle plantar extension	21	6 - 7	15 - 14.5	29 - 30	27 - 24	16 - 14	35 - 41
Waist flexion	0	13	0	1	0	0	2
Neck flexion	24	16	18	16	5	7	16
Left neck lateral bend	0	0	0	3	0	0	0
Shoulder flexion	36	49 - 46	67 - 64	29	33 - 35	60 - 57	36
Shoulder abduction	50	32 - 33	26 - 26.5	27 - 29	40.5	24 - 45	23 - 36
Medial shoulder rotation	86.6	58 - 61	45.5 - 41	71 - 77	74.5 - 74	25.5 - 26.5	50 - 48
Elbow flexion	90	78	45 - 53	61 - 57	94 - 91	78 - 80	51 - 64
Wrist extension	0	0	3 - 0	0	0	0	0
Wrist ulnar bend	0	0	0	0	0 - 9	0 - 3	0
Forearm pronation	N/A	N/A	26	20 - N/A	N/A - 2	16 - N/A	N/A - 5
Forearm supination	30	7 - 10	N/A	N/A - 30	15 - N/A	N/A - 4	14 - N/A
Finger flexion	0	42	60	30	21 - 57	55 - 47	25 - 35

Measurements are in degrees.

This type of data was not available from STS-57 crew members but should be acquired in future studies.

Conclusions/Recommendations

Previous Skylab data were generated from three male participants. Thus, the addition of female participants in the database provides a basis for greater variety in representative postures which should be considered when designing microgravity equipment and tools. Even with the limited amount of data and sampling from one day during the mission, data indicated that a single posture was not all-encompassing. The data also indicated that several postures were evidenced in microgravity, thereby providing a range of postures that may be more representative than the single, all-encompassing posture documented in the MSIS. This suggests that the MSIS was generalized significantly and should be updated with additional data points to provide more representative crew postures. This would also indicate that ESA's concerns about the original determination were correct and that further study should be made of microgravity posture as manifested by a more normally distributed participant population.

To achieve this, as data are acquired on males and females a database of crew postures should be established to record and update NBP posture. Both International and American subjects should be included in the database, since future space activities will involve crew members from all nations for cooperative endeavors such as the Space Station, Mir, and joint international crew flights launched on both the Shuttle and Energia. This database should provide information on crew working postures so that analogous data can be readily applied to workplace and tool design for a wide variety of microgravity environments.

Specifically, in addition to gathering data for defining the zero-g posture, future evaluations should define precise posture requirements for workstation, glove box, and maintenance activities. In addition, the design of foot-restraints and handholds should be considered from a posture standpoint to optimally design work tasks and to reduce crew workload, improve hardware operability, and enhance crew performance.

References

Gunderson, Robert T.; and Bond, Robert L. (1976). Zero-g work station design. JSC IN 76-EW-1.

Jackson, John; Bond, Robert; and Gunderson, Robert (1975). Neutral body posture in zero g. JSC-09551.

Kroemer, K. H. E.; Kroemer, H. J.; and Kroemer-Elbert, K. E. (1990). *Engineering physiology bases of human factors/ergonomics, 2nd. ed.* New York, NY: Van Nostrand Reinhold.

NASA. (1991). *Space Station Freedom Man Systems Integration Standards (MSIS).* June 1991, Houston, TX: NASA. (NASA-STD-3000, Vol. IV).

NASA. (1975). Man-machine engineering data applications of Skylab experiments M478 and M516. Bulletin no 17: Neutral Body Posture in 0-g. Technical Report JSC-09551. Houston, Texas: NASA Johnson Space Center.

NASA. (1978). *Anthropometric source book Volume I: Anthropometry for designers.* (NASA Reference Publication 1024.) Houston, TX: Author.

Whittle, Michael W.; Tobin Herron; and Cuzzi, Jamie (1977). Biostereometric analysis of body form, *Biomedical Results From Skylab*, NASA SP-377, pp. 198-202.

Appendix 1:

Crew Anthropometric Measurements

	Crew 1	Crew 2	Crew 3	Crew 4	Crew 5	Crew 6
Gender	Male	Male	Male	Male	Female	Female
1) Weight	78.0	82.1	72.1	64.0	64.0	45.8
2) Stature	183.9	183.6	178.3	174.7	166.5	151.6
3) Arm reach from wall	87.8	87.3	87.6	85.3	76.5	85.0
4) Thumb tip reach	82.2	81.5	82.3	75.8	70.9	76.9
5) Acromial (shoulder) height	149.6	150.9	147.5	142.6	135.6	122.6
6) Elbow height	116.0	117.4	114.3	109.5	104.6	92.7
7) Waist height	108.4	109.8	106.2	103.5	98.2	89.7
8) Wrist height (standing)	93.2	93.1	89.1	87.0	85.0	71.6
9) Crotch height	87.6	86.4	83.8	84.2	79.4	73.2
10) Ankle height (standing)	11.3	10.5	10.4	9.5	10.5	9.8
11) Sitting height	96.5	94.9	91.6	91.0	87.6	78.6
12) Sitting eye height	86.4	83.5	81.7	81.9	77.1	70.8
13) Knee height	57.2	57.6	56.3	52.7	53.0	46.6
14) Popliteal height	46.1	45.0	44.1	42.5	39.8	37.8
15) Buttock-knee length	63.3	64.6	63.0	61.3	58.3	53.5
16) Buttock popliteal length	50.4	51.7	52.0	50.9	48.2	43.3
17) Shoulder-elbow length	37.1	37.1	36.8	36.4	33.6	32.4
18) Forearm-hand length	48.8	49.0	49.9	46.6	43.4	42.4
19) Hand length	18.4	19.0	18.6	18.5	17.5	17.1
20) Foot length	26.9	28.3	25.8	25.7	23.6	22.6
21) Hand breadth	8.8	8.3	8.3	8.4	7.4	7.5
22) Foot breadth	9.4	11.1	9.5	9.4	8.8	8.5
23) Bideltoid breadth	45.8	47.8	47.2	45.8	40.6	38.5
24) Biacromial breadth	42.6	43.2	42.7	41.9	36.2	35.4
25) Hip breadth	35.5	35.9	34.4	33.2	332.6	30.3
26) Wrist circumference	17.0	17.0	16.0	16.2	13.2	15.8

All measurements are in centimeters, except weight which is in kilograms.

Appendix 2:

Selected Mission Photographs

NASA photograph reference numbers:

- JSC-STS-57-42-9
- JSC-STS-57-42-23
- JSC-STS-57-43-19
- JSC-STS-57-43-006
- JSC-STS-57-202-1
- JSC-STS-57-202-14
- JSC-STS-57-202-18
- JSC-STS-57-202-22